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THE EFFECTS OF POLLUTION CONTROL ON THE NONFERROUS METALS INDUSTRIES

COPPER

Part III

The Economic Impact of Pollution Abatement on the Industry

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CHARLES RIVER ASSOCIATES INCORPORATED · CAMBRIDGE, MASSACHUSETTS

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THE ECONOMIC EFFECTS OF POLLUTION CONTROLS ON THE NONFERROUS METALS INDUSTRY: COPPER

Prepared for
the Council on Environmental Quality

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PREFACE

This report on the economic effects of pollution controls on the copper industry has been organized into three parts comprised of eight chapters. The three parts can be read separately or in conjunction with one another. Part I summarizes the contents of the succeeding two parts, providing a broad profile of the copper industry and outlining the economic effects of pollution controls on the industry. The important points and conclusions of the full report are contained in the first part, with greater detail and analysis in the following two parts.

Part II comprises separate chapters on:

Trends in supply and the technology of production
Consumption
Structure of the industry
Prices
Government policies
The copper industry in the United States

Part III is our detailed analysis of the economic effects of imposing pollution controls on the copper industry.

Much of the information contained here was first published in Charles River Associates Incorporated, *An Economic Analysis of the Copper Industry* (Cambridge, Mass., 1970), which we prepared under contract with the General Services Administration. Data presented in this report if not otherwise attributed is taken from our GSA report.

PART III

Chapter 8
ECONOMIC IMPACT OF POLLUTION ABATEMENT UPON THE COPPER INDUSTRY

According to estimates supplied by the Council on Environmental Quality, the capital costs of installing all additional equipment to meet air and water abatement standards in the primary copper industry are between $311 and $682 million; the operating and maintenance costs of this equipment are between $35 and $76 million per year. This chapter investigates the impact on the copper industry of these enormous financial outlays. The air quality standard in question is 90 percent removal of feed sulfur; the water quality standard is secondary treatment or its equivalent.

The following two sections discuss the nature and costs of the pollution abatement problems in the copper industry. The fourth section describes the probable market trends in the copper industry if no abatement

costs were necessary. We then analyze the impact on such market variables as price, production, consumption, employment, and international trade of the expected abatement costs under a variety of assumptions about the costs and the likely market contingencies.

Sources of Pollution in the Copper Industry

The most serious air pollution problems in the copper production arise mainly in smelter operations. The potential for dust problems in open-pit mining exists, but these problems seem to be easily controllable and usually are controlled. Similarly, effluents from ore crushers can be local nuisances but effective dust collectors are incorporated in the exhaust ventilation systems to control them. Neither the flotation process nor electrolytic refining create significant air pollution problems.[1]

All three main stages in primary smelting emit gases and dust. Roasting produces SO_2 and volatile oxides of arsenic, antimony, lead, and other trace elements. A reverberatory furnace emits these same oxides, with selenium and tellurium in addition. The converters emit SO_2.

Depending on the material being processed, the dusts emitted in smelting may have considerable commercial value when collected and are a serious source of pollution if they are not. Almost complete removal of dust from flue gases is apparently the usual practice.

The problem in air pollution control is the SO_2

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[1]K. V. Nelson, *op. cit.*, p. 176.

emissions. If air pollution were not a consideration, collection SO_2 emitted in copper smelting would be unattractive as a commercial venture. While theoretically it could be used as a source for several basic chemicals as well as sulfuric acid, much better sources exist. The SO_2 from copper smelting is costly to collect because it has been diluted by the large volumes of air required for the smelting process. To produce sulfuric acid, SO_2 concentrates should be 4 to 8 percent. The traditional approach to the problem has been to dispose of SO_2 in the atmosphere through high stacks.

The principal water pollution problem is in electrolytic refining. As discussed in the following section, while water pollution abatement costs are very large relative to total refining costs, the total costs of water pollution abatement are small relative to the total costs of air pollution abatement at smelters.

Costs of Pollution Abatement

According to the mid-range of estimates supplied by the Council on Environmental Quality, the capital costs of installing additional equipment to meet air quality standards (90 percent of feed sulfur) at copper smelters by 1976 will be $313 million, and $28.1 million will be required to meet water quality standards (secondary treatment or the equivalent) at copper refineries. The CEQ estimates for operating and maintenance costs are $35 million for air quality control and $3.1 million for water control in 1976, by which time the federal standards must be met.

CEQ Estimates of Air Pollution Abatement Costs

Table 8-1 presents the data provided by the Council on Environmental Quality on the additional costs to producers of controlling SO_2 emissions from smelters in accordance with federal standards. CEQ estimated that the true costs could reasonably be 10 percent lower or 100 percent higher than these figures. The costs would be lower if plants are able to sell any of the acid produced or if more plants have installed control facilities than assumed in the "most likely" estimate. The costs might be higher if the technology assumed in the middle cost estimate cannot be adapted in practice.

These cost estimates were constructed using several key assumptions. Among them was the assumption that technology would be developed in time to provide the required controls at the projected costs. Other assumptions were that copper production would increase at an annual rate of 2.7 percent, that plants would operate at 100 percent capacity 24 hours a day for 330 days of the year, and, therefore, that capacity would be expanded to maintain this level of capacity utilization. Depreciation was taken to be 7 percent per year and interest was assumed to be 8 percent per year plus 2 percent to cover local taxes.

The total investment required to control existing facilities is estimated to be $266 million and the total required to control the new capacity constructed in the period 1972-1976 is estimated at $47 million. These capital costs are assumed to be phased over the five-year period as shown in the table.

Table 8-1
CEQ ESTIMATES OF COSTS OF CONTROLLING
SO_2 EMISSIONS AT COPPER SMELTERS
(Millions of Dollars)

Costs of Controls	1972	1973	1974	1975	1976
Cost to control existing facilities	13.3	26.6	93.2	106.5	26.6
Cost to control new facilities	9.3	9.4	9.4	9.4	9.4
TOTAL	22.6	36.0	102.6	115.9	36.0
Annual Costs					
Operation & Maintenance	1.7	5.2	17.3	31.0	34.5
Interest	1.6	4.7	15.6	28.0	31.3
Depreciation	1.1	3.3	11.0	19.8	22.0
TOTAL	4.4	13.2	43.9	78.8	87.8

SOURCE: CEQ

ASSUMPTIONS:

1. Fifteen copper smelters were assumed to require control.
2. The interest rate is 10%, including 2% for taxes and insurance.
3. The growth rate of production is 2.67% per year.
4. The depreciation rate is 7% per year.
5. No downtime for installation is envisaged.
6. The investment costs to control existing facilities are phased over the five years -- 5%, 10%, 35%, 40%, 10%, and the investment costs of controlling new facilities are assumed to be linear.
7. No credit for acid by-products was assumed.

(Assumptions continued on following page.)

Table 8-1
CEQ ESTIMATES OF COSTS OF CONTROLLING
SO_2 EMISSIONS AT COPPER SMELTERS
(Millions of Dollars)

(continued)

8. Three smelter models were used:

   Model Plant A (Configuration -- 1 Roaster, 1 Reverberatory Furnace, and 2 Converters) with production of 75,900 tons of copper per year and 45% present sulfur control. The control scheme involved is limestone scrubbing.

   Model Plant B, with production of 75,900 tons of copper per year, 6% present sulfur control, and a control scheme involving an acid plant preceded by a dry precipitator.

   Model Plant C. (Configuration -- 1 Reverberatory Furnace, and 4 Converters) with production of 50,000 tons of copper per year and 10% present sulfur control, and a control scheme involving an acid plant preceded by a dry precipitator.

9. All plants were assumed to operate at 100% capacity, 24 hours a day for 330 days of the year.

The annual cost of abatement, defined to equal operating and maintenance costs of abatement equipment, interest and depreciation, represents the long-run cost to producers of installing and maintaining abatement facilities. As the following table indicates, in the middle cost estimate this per-pound cost (in 1971 dollars) rises from $0.001 in 1972 to $.013 in 1974 and $0.023 in 1976. This latter figure presumably represents the permanent annual per-pound abatement cost. In the low cost estimate the long-run cost is $0.021 per pound while the high long-run cost estimate is $0.046 per pound.

	Assumed U.S. Smelter Production (thousands of short tons)	Total "Annual"[1] Abatement Cost, Middle Estimates (Million Dollars)	Abatement Cost/Pound (Dollars Per Pound)		
			Low Estimate	Middle Estimate	High Estimate
1970	1620	--	--	--	--
1971	1664	--	--	--	--
1972	1708	$ 4.4	$0.001	$0.001	$0.002
1973	1752	13.2	0.004	0.004	0.008
1974	1796	43.9	0.012	0.013	0.026
1975	1840	78.8	0.019	0.021	0.042
1976	1884	87.8	0.021	0.023	0.046

[1] Includes operation and maintenance costs, interest, and real depreciation.

CEQ Estimates of Water Pollution Abatement Costs

As Table 8-2 shows, the additional investment costs of water pollution abatement at copper refineries are over $28 million; the "annual" costs rise to $7.6 million by

Table 8-2
COSTS OF CONTROLLING WATER
POLLUTION IN COPPER REFINING
(Millions of Dollars)

Investment Costs	1972	1973	1974	1975	1976
Cost to control existing facilities	3.98	4.19	4.39	4.60	4.82
Cost to control new facilities	1.13	1.17	1.21	1.26	1.30
TOTAL	5.11	5.36	5.60	5.86	6.12
Annual Costs[1]					
Operation & Maintenance	0.78	1.56	2.36	3.16	3.98
Interest	0.41	0.84	1.29	1.75	2.24
Depreciation	0.26	0.52	0.80	1.10	1.40
TOTAL	1.45	2.92	4.45	6.01	7.62

[1]Annual costs have been adjusted to include the annual costs of the "new facilities" covered in "Investment".

SOURCE: CEQ

ASSUMPTIONS:

1. Copper refineries would apply equalization, coagulation, sedimentation, flotation, and neutralization to 100% of process wastewater.
2. The interest rate is 8%.
3. The growth rate of copper production is 4.2%.
4. The depreciation rate is 5% per year.
5. Some downtime for installation is included.
6. The investment costs are phased on a straight line basis from 1971 to 1976.

1976. A reasonable range for the true costs is given as from 25 percent below these estimates to 130 percent above.

As the table below indicates, in the middle estimate the annual abatement cost per pound rises from $0.0007 in 1972 to $0.0010 9n 1974 and $0.0016 in 1976. The low estimate in 1976 is $0.0012 while the high estimate is $0.0037.

ESTIMATED LONG-RUN WATER POLLUTION ABATEMENT COSTS

	Electrolytically Refined Copper Production (thousands of short tons)	Total "Annual" Abatement Cost, Middle Estimate[1] (Million Dollars)	Abatement Cost/Pound (Dollars Per Pound)		
			Low Estimate	Middle Estimate	High Estimate
1970	1989	--	--	--	--
1971	2042	--	--	--	--
1972	2100	$1.45	$0.0002	$0.0003	$0.0007
1973	2159	2.92	0.0005	0.0007	0.0016
1974	2220	4.45	0.0008	0.0010	0.0023
1975	2381	6.01	0.0010	0.0013	0.0030
1976	2443	7.02	0.0012	0.0016	0.0037

[1] Includes operation and maintenance costs, interest, and real depreciation.

CEQ Estimates of Total Abatement Costs

Using the CEQ estimates, the table below shows that in the middle cost assumption the per-pound combined cost of both air and water pollution abatement rises to $0.0025 by 1976; the low estimate is $0.022 and the high estimate is

$0.50. Most of these costs are incurred at the smelting stage.

RANGE OF TOTAL ESTIMATED ABATEMENT COSTS FOR PRIMARY REFINED COPPER
(Dollars per Pound of Copper)

	Low	Middle	High
1972	$.001	$.001	$.003
1973	.005	.005	.011
1974	.013	.014	.028
1975	.020	.022	.045
1976	.022	.025	.050

Other Factors Affecting Abatement Costs

The true impact of pollution abatement will depend on such factors as the timing of the expenditures, the level of capacity utilization, the tax treatment of these expenditures, and the availability of the required technology. The estimates are also affected by such factors as the choice of interest and depreciation rates, but variation in these factors would not cause major changes in the cost estimates.

The Level of Capacity Utilization

The costs calculated above assume a specific level of capacity utilization -- 24 hours a day for 330 days a year. If a different level of utilization is assumed, it will give a different cost per pound for abatement. As an approximation we could assume that the operations and maintenance costs are proportional to the level of capacity

utilization. The interest and depreciation costs would, of course, be unaffected by fluctuations in output. Thus, if output in 1976 were 10 percent lower than projected, air pollution abatement costs for the industry would be reduced by $3.5 million (10 percent of operation and maintenance) to $84.3 million, or $0.0226 per pound as opposed to $0.0233 at the assumed capacity. The effect on water abatement costs of a 10 percent change in output is roughly the same proportion. Thus, a 10 percent change in production will only affect the abatement cost per pound of copper by a negligible amount.

The Tax Treatment of Abatement Costs

For tax purposes, the "guideline" useful life assignable to assets used by the nonferrous metals industries is 14 years, to which the depreciation schedules used in Table 8-1 and 8-2 conform. Firms are allowed to vary this time from 20 percent shorter to 20 percent longer. However, the Tax Reform Act of 1969 created special incentives for the installation of pollution control equipment. It permits the equipment to be amortized over five years regardless of its useful life. Of the total capital cost of pollution equipment, 20 percent can be used to reduce taxable income each year for five years. Another tax incentive currently being considered is the investment tax credit, which may allow firms to deduct from their taxes up to 7 percent of the cost of capital equipment.

Both of these incentives will cause the after-tax costs of pollution equipment to be lower than otherwise. However, while the dollar figures involved are large in

absolute terms, the percentage reduction in control costs will only be moderate. For example, if a firm makes a $14 million investment, the accelerated depreciation schedule allows it to deduct $2.8 million in depreciation for the first 5 years instead of $1 million. The annual reduction in taxes during the first 5 years is therefore $938,000 (52 percent times $1.8 million). However, the firm will pay increased taxes for the next 9 years of $520,000 (52 percent times $1 million). For reasonable values of the discount rate, the average annual reduction in the percent value of the firm's taxes will be a fairly small percentage of the cost of the equipment.

The Timing of Abatement Expenditures

The CEQ cost estimates are made on the assumption that the bulk of the control costs will be incurred in 1974 and 1975. If these costs must be incurred primarily in 1972 and 1973 instead, the burden on producers will clearly be more severe. They would have to raise the necessary capital earlier and because the present value of a dollar spent one or two years in the future is greater than the present value of a dollar spent three or four years in the future, the present value of the total investment cost would obviously be larger.

A more important effect, however, or moving up much of the construction to 1972 and 1973 is that it may force producers to adopt inefficient control technologies. The CEQ cost estimates assume that certain intended technologies will work in practice. Several industry sources have indicated that even if these technologies work at least several years will be required to develop them, and that

if firms have to embark on a crash program to meet abatement standards going into effect over the next several years, it will be necessary to use inefficient techniques of control. This point is discussed further below.

Other Estimates of Control Costs

Two recently released studies of abatement costs in the copper market have concluded that they will be nearly as large or larger than the high range of the costs estimated by CEQ.

A study performed by Fluor Utah for Kennecott questions CEQ's assumptions about the availability of technology to meet the proposed standards.[1] Fluor estimates that if the required technology could be developed, annual ambient air standards and the 90 percent sulfur recovery standard could be met using limestone scrubbers backed up with caustic scrubbers for an industry-wide cost of $345 million. Fluor further estimates that the standards could be met using acid plants plus scrubbers for a cost of $320 million. While these estimates are consistent with CEQ's estimates, Fluor does not feel that the necessary technology can be developed in time. With existing technology, the Fluor Utah study estimates that ambient air standards can be met at a cost of $572 million using production curtailment and acid plants and by constructing additional capacity to replace the curtailed production.

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[1]Fluor Utah Engineers & Construction, Inc., *The Impact of Air Pollution Abatement on the Copper Industry*, San Mateo, California, 1971.

However, this technology would not satisfy the 90 percent sulfur recovery standard. In yet another alternative, Fluor Utah estimates that both ambient and emission standards could be achieved at a cost of $1.2 billion by replacing the entire U.S. smelting capacity with new plants.

A study recently published by the U.S. Bureau of Mines examines the detailed plans for pollution control measures in 14 smelters operated by seven companies.[1] The smelters represent 98 percent of domestic primary copper capacity. The total capital cost was estimated to be $598 million plus or minus 15 percent ($90 million). For individual companies the estimated capital cost ranged from $6 million in the case of a small smelter with an exceptionally low percentage of sulfur in its ores to $218 million for a firm having an annual smelter output capacity of 380,000 tons of copper. Including capital and operating costs, the estimates of long-run costs of air pollution control for four respective firms, accounting for 40 percent of U.S. primary capacity, were $0.008, $0.024, $0.044 and $0.045 per pound.

The Fluor Utah and the Bureau of Mines studies yield estimates of control costs that lie in the upper range of the CEQ cost estimates. None of the estimates, however, include a cost for disposal of sulfur extracted from the feed. In some smelters the sulfur may be converted to sulfuric acid and used for leaching, thus increasing sulfur

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[1] *Control of Sulfur Oxide Emissions in Copper, Lead and Zinc Smelting*, Information Circular 8527, Staff, Bureau of Mines, U.S. Department of the Interior.

recovery somewhat. One smelter is located on tidewater and might be able to ship acid or SO_2 to markets at a profit, or at least, with small loss. It seems likely, however, that in most cases the cost of transporting the sulfur product to a market area will, at best, be close to the market price of the product.

Long-Run Impact of Pollution Abatement Costs on the Copper Industry

Pollution controls directly affect the copper market by increasing the costs of primary smelting and electrolytic refining and indirectly affect the copper market by raising the cost of metals that compete with copper. The long-run increase in costs associated with the new pollution controls should have the same direct effect on the copper market as any other commensurate increase in long-run costs (for example, higher wage rates or materials costs).

In analyzing the effects of abatement costs on the copper market, we will first examine the probable trends in the copper market in the absence of abatement costs. We will then analyze the impact on these trends of the estimated abatement costs.

We must emphasize, however, that it is exceedingly difficult to forecast accurately trends in the domestic copper market. As our earlier chapters on the structure of the industry show, the copper market is one of the most complex markets of all the nonferrous metal markets even under "normal" conditions. The behavior of the

domestic producers has been particularly difficult to analyze. As we explained in Chapter 5 there have been protracted periods during which the U.S. producers have rationed copper at prices below the foreign open market price (as represented by the LME price). The available evidence suggests that the U.S. producers are much more concerned about maintaining low and stable prices than are the foreign producers. The explanation offered by the producers for rationing copper at prices below open market prices is generally that they fear that increases in the list price of copper would induce long-run substitution of other materials for copper. It is also possible, however, that pressure from the U.S. government has prevented the domestic producers from raising prices as much as they would like. At any rate, it is clear that if these conditions persist in the future, the U.S. producers could increase the price of copper without inducing substantial foreign competition in the U.S. market. This conclusion would be obviously true during periods of rationing in the United States; during these periods U.S. producers could raise the list price of copper without any loss to imports. This conclusion might also be valid even during periods of nonrationing, as some participants in the copper market (the Chilean government, for example) have expressed strong desires to increase the price of copper.

For a number of reasons, however, it is impossible to forecast accurately the extent to which the foreign market will interact with the U.S. market. First, even under "normal" market conditions it is impossible to

predict the extent to which domestic producers will ration copper during the next decade. The extent of this rationing depends on the rate of expansion of domestic production capacity, the persistence of the domestic producers' belief that the loss of substantial short-run profits through rationing will be offset by the stimulation by low prices of long-run demand, and the extent of government pressures to keep prices low. None of these factors can be accurately foreseen.

Second, the copper market is currently undergoing radical changes in its structure because of the increasing decision-making role of national governments in copper production. This factor could completely alter the supply behavior of foreign production. For example, foreign producers might engage in a capacity expansion race to enlarge revenues from copper production as rapidly as possible. This would in turn drive down open-market prices and could result in increased exports of copper to the United States. On the other hand, there are indications that production costs in certain foreign countries have increased since their governments have taken a greater interest in copper production. In addition, the major foreign producing countries have formed a trade association that may be able to operate effectively as a cartel, restricting output to increase price. Either of these factors could result in higher open-market prices and smaller exports to the United States.

As a result of issues such as these, we caution against literal interpretation of our description of probable trends in the copper market in the absence of abatement costs. However, we feel the scenario discussed in

the next section is fairly reasonable and serves as a useful base for the impact analysis. As the impact analysis itself depends on the assumptions made about the interaction between domestic and foreign producers and the persistence of the "two-tier" price system, the impact analysis is performed under a range of alternative assumptions about these factors.

Probable Trends in the Copper Market in the Absence of Pollution Controls

Our analysis of probable trends in the copper market relies in part on the findings of our econometric model of the copper market (described in Chapter 5) and in part on our analysis of recent market events. We did not formally simulate our model, but in our analysis we use the following long-run supply and demand elasticities derived from the model:

Elasticity of U.S. demand with respect to the producers' price	-1.09
Elasticity of U.S. demand with respect to the index of durable manufactures	1.21
Elasticity of U.S. refined copper production with respect to the producers' price	0.85
Elasticity of U.S. refined copper with respect to the mining costs	-1.10

These elasticities were calculated statistically from annual data on the copper market for the period 1947-1970. The demand elasticities measure the percentage decrease in domestic consumption that occurs in response

to a 1 percent increase in real price, and the increase in consumption in response to a 1 percent increase in the index of durable manufactures. Similarly, the supply elasticities measure the production responses to changes in real price and production costs (as represented by the index of mining costs).

To develop our forecasts we assume:

- that general economic activity as represented by the index of durable manufactures will grow at an average rate of 4.0 percent per year between 1970 and 1980;
- that the supply of scrap as a percentage of total supply remains constant in the long run (a reasonable assumption, as the reservoir of scrap is dependent on past primary production);
- that net stock accumulation rises at the same rate as consumption;
- that production capacity increases at an annual rate of 2.7 percent;
- that the aluminum price in the absence of abatement costs remains constant in real terms;
- and that both the deflated producer price and the open-market price of copper increase at a rate of 1 percent per year.

This increase in price approximately equilibrates supply and demand in the domestic market.

The projected long-run average annual growth in demand is 3.8 percent, comprised of a 4.8 percent growth induced by the increase in the index of durable manufactures, and by a negative growth of 1 percent induced by the increase in price. Supply is projected to grow at a rate of 3.6 percent (comprised of 2.7 percent for the increase in

capacity and 0.9 percent for the increase in price).

In 1970 total U.S. industrial consumption of copper was 2,971,000 short tons and net stock accumulation and exports were 139,200 short tons. Total U.S. primary copper production was 1,705,900 short tons and total U.S. scrap supply was 1,360,300 short tons. Projecting supply and demand at the annual growth rates discussed above yields estimates of 4,169,000 short tons for net supply and 4,250,000 short tons for net demand in 1980.

The Impact of Abatement Costs on the Copper Market

As mentioned earlier, a major difficulty in forecasting and analyzing the copper market arises in the treatment of the two-tier price system (in which the domestic producer price is substantially below the foreign price of copper) and the interaction between domestic and foreign producers. As the copper market is currently in a state of flux it is very difficult to reach any strong conclusions about these factors. In our impact analysis we therefore present a range of results, calculated under two extreme assumptions:

(1) that foreign copper does not compete in the domestic market and an equilibrium price is achieved, after imposition of abatement costs, which equates domestic demand and domestic supply; and

(2) that foreign competition prevents any increase in price as a result of abatement costs.

The first case can arise if the two-tier price system is still in effect in 1980, as in that case producers can increase their price by the full amount of control

costs without stimulating an increase in imports. This case can also arise even if the two-tier price system is not in effect if foreign producers refrain from expanding their exports when the domestic producers raise prices. In the second case we make the equally extreme assumption that any increase in prices as a result of abatement costs will cause such a flood of imports that the increased price cannot be maintained. The actual impact of the abatement costs should be somewhere in between these two cases.

The analysis is also performed using both the middle- and high-cost estimates provided by CEQ. No analyses were performed using the low-cost estimates, as these cost estimates are very close to the middle-cost estimates and therefore would yield essentially the same results in the impact analysis.

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Effects on Price, Production, and Consumption Under the Middle-Cost Assumption

According to the middle-cost assumptions, the long-run pollution abatement cost is $0.025 per pound of copper. With severe foreign competition none of this cost could be passed on to consumers. The increase in production costs would not be offset by price increases and there would be a resultant decline in supply in the long run of 6.9 percent (using the elasticity estimates presented above). On the other hand, if there were no foreign competition, prices could be increased with the result that supply would increase. Assuming no increase in imports, supply and demand would be equilibrated at a price 4 percent above the no abatement cost case; under our assumptions the price would rise to about $0.66 in 1970 dollars.

The effects on price, production, consumption, and imports under the two assumptions about foreign competition can be summarized as follows:

LONG-RUN EFFECTS ON THE COPPER MARKET OF AN INCREASE IN COSTS OF $0.025 PER POUND

	Little Foreign Competition	Severe Foreign Competition
Producer Price of Copper in 1980 (1970 dollars per pound)	$0.66	$0.64
U.S. Supply of Primary* Refined in 1980 (thousand short tons)	2251	2173
U.S. Supply of Secondary Refined and Scrap in 1980 (thousand short tons)	1768	1708
Net Imports of Copper in 1980 (thousand short tons)	36	369
U.S. Consumption of Copper in 1980 (thousand short tons)	4055	4250

*About 56% of total copper supply is assumed to be primary copper, the remainder refined and unrefined scrap.

Effects on Price, Production, and Consumption Under the High-Cost Assumption

According to the high-cost assumption the long-run pollution abatement cost is $0.050 per pound of copper. With severe foreign competition there would be no price increase and the assumed supply rate would be 14.2

percent below the no abatement cost supply rate. Domestic consumption would not be affected and the undersupply would be made up by imports. In the case in which there is no foreign competition the price of copper would rise by 8 percent, to about $0.69 per pound, at which point domestic demand would approximately equal domestic supply. The effects on the market in the high-cost case are summarized below.

LONG-RUN EFFECTS ON THE COPPER MARKET OF AN INCREASE IN COSTS OF $0.050 PER POUND

	Little Foreign Competition	Severe Foreign Competition
Producer Price of Copper in 1980 (1970 dollars per pound)	$0.69	$0.64
U.S. Supply of Primary Refined in 1980 (thousand short tons)	2162	2003
U.S. Supply of Secondary Refined and Scrap in 1980 (thousand short tons)	1698	1574
Net Imports of Copper in 1980 (thousand short tons)	8	673
U.S. Consumption of Copper in 1980 (thousand short tons)	3868	4250

NOTE: About 56% of total copper supply is assumed to be primary copper, the remainder refined and unrefined scrap.

The Effects on the Copper Industry of Pollution Controls on Aluminum

It should be noted that all the calculations made in this chapter are based on the assumption that there is no increase in the price of aluminum. Statistical analysis performed by CRA in other studies of the aluminum and copper markets reveal that there is a strong and significant substitution effect between copper and aluminum.[1] As a result, if the aluminum price increases by as much or more than the copper price, much of the adverse impact of pollution controls on the copper industry might not occur. The positive effects on copper demand of higher aluminum prices would offset to some extent the negative effects of higher copper prices.

The costs of pollution controls on the aluminum industry are estimated to be between $0.020 and $0.032 per pound. If aluminum prices increase by this amount, much of the adverse effect on U.S. copper consumption of higher copper prices would be offset.

For this reason the estimates presented above of the adverse effects of copper control costs should be regarded as maximum estimates. The actual impacts of the controls could still conceivably be near the upper end of the range estimated above for two reasons. First, if copper control costs are near the upper end of our assumed range they would be substantially greater than the aluminum control costs. Second, the effects of foreign competition could almost be as

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[1]Charles River Associates Incorporated, *An Economic Analysis of the Aluminum Industry* (1971) and *An Economic Analysis of the Copper Industry* (1970).

severe with higher aluminum prices as they would with lower aluminum prices.

The Effects of Off-Shore Smelting of U.S. Copper Ore

We have assumed so far that all U.S. ore that is mined will be smelted in the United States. It is conceivable, however, that U.S. mined copper concentrates could be shipped to foreign copper smelters that are not subject to pollution controls and smelted there. The copper could then be imported back to the United States as smelted, refined, or even fabricated copper.

A complete analysis of this possibility would require a detailed examination of both U.S. and foreign production and transportation costs. While such an analysis is beyond the scope of this study, it is possible to examine some of the considerations involved in the analysis.

Suppose that the domestic and foreign costs of production are identical without pollution controls and that only the U.S. smelters are controlled. Suppose further that the internal costs of transporting copper concentrates and metal net out in the analysis -- that is, that the internal costs of transporting copper concentrates to seaports and transporting imported copper metal to consumer markets are approximately equal to the internal transportation costs of concentrates and metal if the ore is smelted domestically. In this case, the only difference in costs between smelting ores domestically and abroad is the transoceanic

transportation cost. Although these costs obviously vary depending on such factors as the length of haul, the particular route in question, and loading and unloading costs, a good rule of thumb for ocean transportation of copper concentrates or metal is $0.01 to $0.02 per pound each way, with the actual figure in most cases being near the lower end of this range. Thus, the added costs of smelting U.S. concentrates abroad and then importing copper metal are between $0.02 and $0.04 per pound.

Under these assumptions, therefore, abatement costs (affecting U.S. producers only) in the range of $0.02 to $0.04 per pound or greater may induce some domestic concentrates to be shipped abroad for production of copper metal. As the CEQ cost estimates are in the range of $0.022 to $0.050 per pound, it seems that this possibility may arise.

It is difficult to predict the exact level of abatement costs at which exporting copper concentrates becomes attractive because a number of other factors must also be considered. For example, there probably would be some increase in internal transportation costs if concentrates were exported, as domestic smelters can clearly be located more efficiently from the point of view of internal transportation than can foreign smelters. In addition, many foreign countries are also planning to impose pollution controls on copper smelters, which would reduce the scope for locating new smelters abroad to process U.S. concentrates.

Even if U.S. abatement costs are high enough to make exportation of U.S. concentrates attractive, these

costs will probably not in general be great enough to induce U.S. producers to shut down existing smelters, although a few marginal smelters might be forced to close. Therefore in the most extreme case there would be no expansion in U.S. smelting capacity from its present level of 1,730,000 short tons; once production reaches this capacity all additional ore production would be exported. Depending on the assumptions made about control costs and foreign competition, we found earlier that domestic copper production in 1980 with pollution controls would be between 2,000,000 and 2,250,000 short tons. Thus, in our most extreme scenario in which no new domestic smelter capacity is constructed, between 270,000 and 520,000 short tons of copper concentrates would be exported in 1980 for processing by foreign smelters. We caution, however, that with the available data we can make no judgment about the likelihood of this scenario.

The Effects of the Controls on Existing Smelters

It appears that in general most existing smelters in the United States will continue to operate after imposition of pollution controls. Nevertheless, one firm appears likely to close a major custom smelters in the Pacific Northwest if the local pollution control regulations are implemented and another firm has already decided to close a smelter at Douglas, Arizona, whose production has been largely custom. The smelter in the Norhtwest is located in a sizeable metropolitan area but since the area is already depressed the impact on

unemployment and local trade could be significant. The smelter at Douglas has 645 employees and is situated in an area where 11 percent of the labor force of 20,900 is employed in the mining industry. Again, the impact on the local economy is likely to be significant.

Another smelter at Superior, Arizona, is to be closed, with conflicting reports as to the reason. The owner is expanding another smelter at San Manuel in the same county and it appears that the smelter at Superior might have closed when the new capacity came into production, even without pollution control considerations.

Effects of Controls on U.S. Employment

Using data presented in Chapter 7 of this report we estimated employment in all stages of copper production for 1970 to be around 54,000 employees. If employment is in constant proportion to production, we estimate total 1980 employment without pollution controls of 76,900 employees. Using the estimated effects of the control costs on domestic production, we get the following estimates of the effects of controls on U.S. employment.

DECREASE IN EMPLOYMENT FROM THE ANNUAL RATE OF 76,900 WITHOUT CONTROLS

	Little Foreign Competition	Severe Foreign Competition
Middle-Cost Assumption	2,770	5,300
High-Cost Assumption	5,690	10,900

It should be noted that in no case does employment fall below the current rate.

The Regional Impact of Pollution Controls

The state most likely to be affected adversely by pollution abatement costs is Arizona. The mining industry is the state's second largest source of income and copper contributes over 90 percent of mining income. The income for copper in 1969 was $860 million.

Arizona smelters employ between 2,500 to 3,500 people in Arizona. Wages paid to mining and smelting employees in 1970 amounted to $202 million. The copper industry is one of the largest consumers of the construction and transportation industries' outputs in the state and supports much of the state's retail trade and services.

Three smelters, accounting for 21 percent of U.S. smelter capacity, are located in Gila County -- two in Hayden and one in Miami. Two smelters are located in Pinal County which adjoins Gila, one at San Manual, the other at Superior. There are plans for closing the Superior smelters and enlarging the San Manual smelter. The mine-mill-smelter complex at Morenci is the principal employee in Greenlee County. A smelter at Douglas in Cochise County may shut down; pollution controls may be a factor in determining whether or not this occurs. The Douglas smelter employs 645 persons and has a payroll of $6 million. The population of Douglas is 12,300. An eighth smelter is located at Ajo in Pima County, the County in which Tucson is situated.

Copper mining is extensive throughout Arizona, and the economies of four counties rely greatly on it -- Graham, Mojavi, Yavapai, and Yuma.

The primary copper smelters in other states are generally not crucial elements in their state's economies, although they are important to the cities where they are located (except possibly for Tacoma, Washington and El Paso, Texas, which are large cities with employment distributed among several industries. The Tacoma smelter may be closed if the owners and the local air pollution control authority cannot reach agreement on control standards. Closing the Tacoma smelter would affect mining employment in Arizona.)

A smelter in White Pine, Michigan is in the peculiar position of having too little sulfur in its feed. Apparently the result is that satisfying the 90 percent emission standard is more difficult than for most smelters and may be infeasible.

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